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**Koonen, A. M. J.; Popov, M.; Wessing, Henrik**

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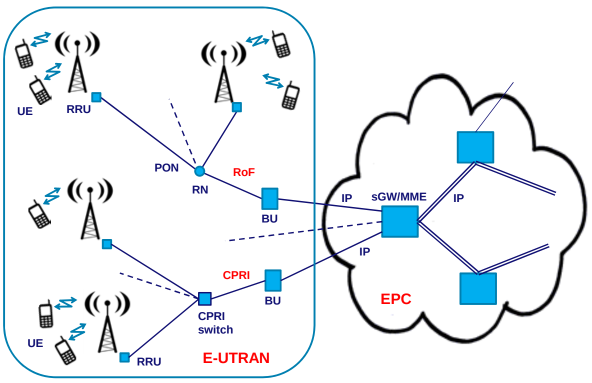
# Upper Bound for Energy Efficiency in Multi-Cell Fibre-Wireless Access Systems

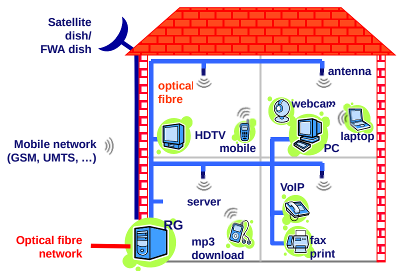
A.M.J. Koonen[1], M. Popov[2], H. Wessing[3]
[1] COBRA Institute, Eindhoven Univ. of Technology, Eindhoven, The Netherlands; a.m.j.koonen@tue.nl
[2] ACREO Swedish ICT AB, Kista, Sweden; mikhail.popov@acreo.se
[3] DTU Fotonik, Techn. Univ. of Denmark, Lyngby, Denmark; hewe@fotonik.dtu.dk

**Abstract** *Bringing radio access points closer to the end-users improves radio energy efficiency. However, taking into account both the radio and the optical parts of a fibre-wireless access system, the overall system energy efficiency has an upper bound determined by the relation between the energy consumption of the optical and wireless parts.*

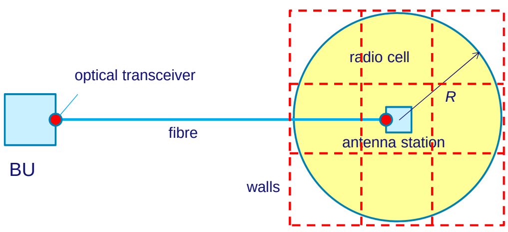
## Fibre-fed LTE access




## Wired/wireless converged indoor network




## Single large radio cell




Free-space radio channel:

$$P_{rec} = P_{transm} \cdot \left(\frac{\lambda}{4\pi R}\right)^2 \cdot G_{AT} \cdot G_{AR}$$

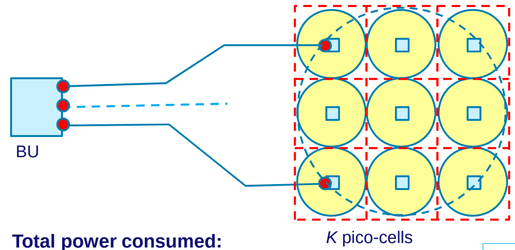
**Total power consumed**:

$$P_{tot,single\ cell} = P_{radio} + P_{optical} = c \cdot R^{\gamma} \cdot A_1^{\sqrt{N}-1} \cdot P_{mob} + 2 \cdot P_{trx}$$

where

- $c$ includes antenna gains and OE signal conversion efficiency
- $N$ is number of rooms
- $A_1$ is attenuation factor per wall crossing
- $\gamma$ is path loss exponent ($\gamma$=2 in free space, $\gamma$ may be up to 4 or more inside buildings)
- $P_{mob}$ is received radio power needed at mobile device
- $P_{trx}$ is power needed in optical transceiver

## Fibre-fed radio pico-cells




**Total power consumed:**

number of rooms $N$ ≥ number of pico-cells $K$

$$P_{tot,picocells} = P_{radio} + P_{optical} = c \cdot K \cdot \left(\frac{R}{\sqrt{K}}\right)^{\gamma} \cdot A_1^{\sqrt{N/K}-1} \cdot P_{mob} + 2 \cdot K \cdot P_{trx}$$

## Total power consumption: pico-cells vs. single cell

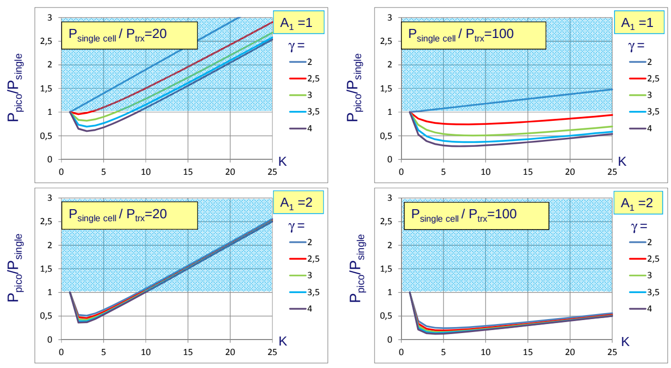
$$\frac{P_{tot,picocells}}{P_{tot,single\ cell}} = \frac{K^{1-\gamma/2}}{A_1^{\sqrt{N}-\sqrt{N/K}}} + \frac{2K \cdot P_{trx}}{P_{tot,single\ cell}}\left(1 - \frac{K^{-\gamma/2}}{A_1^{\sqrt{N}-\sqrt{N/K}}}\right)$$

is dependent on number $K$ of pico-cells , must be <1 for total power saving.
For $A_1$=1 (no walls), total power consumption is minimum for

$$K = \left[\frac{\gamma-2}{2}\left(\frac{P_s}{2P_{trx}} - 1\right)\right]^{2/\gamma}$$

## Energy savings by pico-cells

- $N$=25 rooms




## Concluding remarks

- Radio-over-fiber based pico-cell techniques can improve not only the capacity but also the energy efficiency of wireless networks.
- As long as the number of pico-cells stays below an upper bound, the total power consumption of the network is less than that of a single-cell network
- Total power consumption is minimized by optimizing the number of pico-cells.
- The optimum number of picocells increases and the attainable minimum power consumption decreases when radio path loss exponent increases, wall losses increase, and/or RoF transceiver power consumption decreases.

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